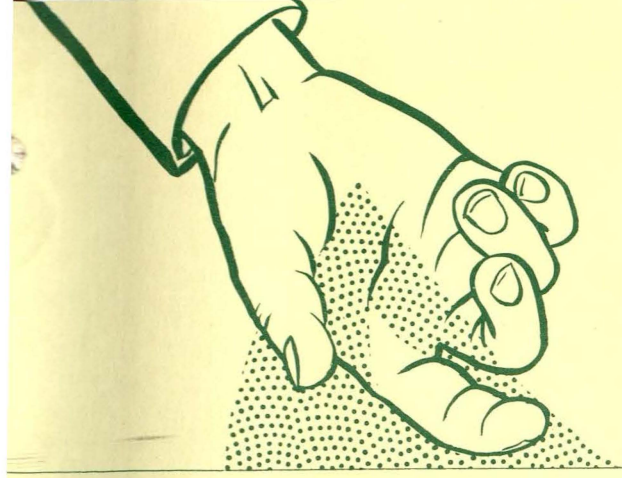

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EUGENE I. ROE

Direct Seeding of Conifers in the Lake States:

A REVIEW OF PAST TRIALS

Direct-seeded jack pine 10 years old and 15 feet tall

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LAKE STATES FOREST EXPERIMENT STATION
M. B. Dickerman, Director
FOREST SERVICE
U.S. DEPARTMENT OF AGRICULTURE

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FOR YOUR REFERENCE FILE

Four abstract cards are included at the back of the report for the reader's convenience.

Direct Seeding of Conifers in the Lake States: A Review of Past Trials

By Eugene I. Roe[1]

During the past 2 or 3 years, there has been a considerable renewal of interest in direct seeding in the Lake States. This has been brought about partly by the soaring cost of forest planting and partly by the excellent results being obtained with aerial seeding of pines in the deep South (Derr and Mann, 1959; Mann and Derr, 1961).[2]

As a result, various agencies have installed small-scale exploratory seeding trials, and others have shown much interest in such tests. Since a coordinated, cooperative effort should produce quicker results than the individual approach, a regionwide meeting of those interested was held at Grand Rapids, Minn., on March 13, 1962, to exchange views and to decide on needs.

For background, much of the material in the following report was presented. Since then, other tests made in the Lake States and Canada have come to light, and these have been added. Any trials made since 1958 are not included in the review.

Despite the title of this paper, direct seeding in the Lake States has not been limited to coniferous species. Some work has been done with hardwoods, particularly with the seeding of oaks and basswood in Wisconsin. But there is little interest at present in the forest planting of such hardwoods and even less in seeding them. So they will be mentioned only in passing in this report.

EARLY WORK

Interest in direct seeding in the Lake States and adjacent Canada goes back at least 40 years.[3] In 1937, Shirley summarized the work that had been done on the National Forests and elsewhere in the Lake States region. Briefly, he reported as follows (**Shirley, 1937**):

Since 1926, when the first known trial was made, some 130 different seedings had been tried in the three Lake States, using 20 distinct methods and involving 18 species. Some of these must have been on a sizable scale, for their aggregate area was over 300 acres.

Methods tested, all on upland, mostly sandy soils, included different kinds of site preparation and seeding methods in both fall and spring. Seed was sown:

1. Without site preparation
2. On land that had been plowed either completely or in part
3. On soil that had been exposed by disks or spring-tooth harrows
4. On burns, both after wildfire and prescribed burns
5. On scalps
6. On spots prepared so as to provide shade or make them inconspicuous to birds and rodents.

Seeding methods included:

1. Broadcast sowing
2. Spotting with and without covering
3. Drilling the seed by hand or with small seeders such as the Planet Jr. garden seeder.

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[1] *The author is a research forester at the Lake States Forest Experiment Station. The Station is maintained by the Forest Service, U.S. Department of Agriculture, at St. Paul 1, Minn., in cooperation with the University of Minnesota.*

[2] *Names and dates in parentheses refer to Literature Cited at the end of the report.*

[3] *Except as otherwise indicated, tests of direct seeding in the northeastern United States and in eastern Canada have not been included because of the great differences in climate between those regions and the Lake States.*

Most of the tests did not attempt to protect the seed against rodents and birds. In a few areas poison bait had been distributed; in others seed spots were covered with conical screens; and on still others, the seed was dusted with red lead or sprayed with sulphonated linseed oil. Occasionally, a light dressing of alum was used to reduce losses from damping off.

The species tested included all of our commercial northern conifers except black spruce and hemlock, eight hardwoods (including two oaks, yellow birch, basswood, and white ash), and the exotic conifers, ponderosa and Scotch pines, Norway spruce, and European larch.

Shirley examined most of the seeded areas in the fall of 1936. He found that, although 60 percent of the seedings had shown better than 50-percent stocking at the end of their first year, only 15 percent of the areas were still so stocked. Much of the loss had been caused by the severe summer droughts of 1933, 1934, and 1936. Other important factors were lack of site preparation, destruction of the seed by rodents and birds, and failure to release the seedlings in their early years from the competition of grass, herbs, and brush. In some species, germination had been poor because no pretreatment was given the seed.

Seedings of only three species, jack pine, red oak, and bur oak, had been successful and these only on sites free from both aggressive competition and seed-destroying rodents and also receiving abundant, well-distributed rainfall during the first two growing seasons. Seedings of all other species had failed. Shirley, therefore, concluded that direct seeding was a poor substitute for planting.

AURORA JACK PINE SEEDING

Shirley's unfavorable report, however, did not prevent the installation of what is probably the most ambitious seeding job yet attempted in the Lake States. During August 1936, the Aurora Ranger District of the Superior National Forest had a 30,000-acre fire which completely destroyed the powder-dry layer of heavy duff and reduced the rodent population to practically none. Two of the basic requirements for a successful seeding were, therefore, present. Since the Forest had a supply of jack pine seed — the most promising species for direct seeding in the Lake States — the Forest officers decided to take a chance on the weather conditions and sow as much of the burn as possible.

Seed was broadcast with Cyclone seeders on the crusted snow of three forties in late March and early April 1937, and about 155 acres of bare ground were sown during early to late May. Part of the latter area was harrowed with a spike-harrow both before and after seeding, some was harrowed after seeding, and the rest had no soil-surface treatment. Three pounds of dry seed were sown per acre on all blocks, as prior tests had indicated only about 20-percent germination (Roe, 1951).

Fortunately, the drought broke. Rainfall in the 1937 growing season was abundant and well distributed, and maximum temperatures were not as high as in 1936. As a result, all areas showed a stocking of 9,000 to 13,000 seedlings per acre that fall except for the snow seedings, which were virtual failures. Subsequent years were also favorable, and the seedlings developed so rapidly that no release measures have ever been needed. Although considerable mortality has occurred, the stands have been so dense from the start as to present a thinning problem (fig. 1). Apparently, the seed had been of considerably better quality than was realized. One pound per acre would likely have proved sufficient, and the investment in soil treatment (harrowing) only aggravated the thinning problem (Roe, 1951).

The score here is 155 acres of overstocked jack pine, 40 acres partially stocked, and 80 acres a failure. The poor areas are the three forties that were snow-seeded; the overstocked are those seeded on bare ground.

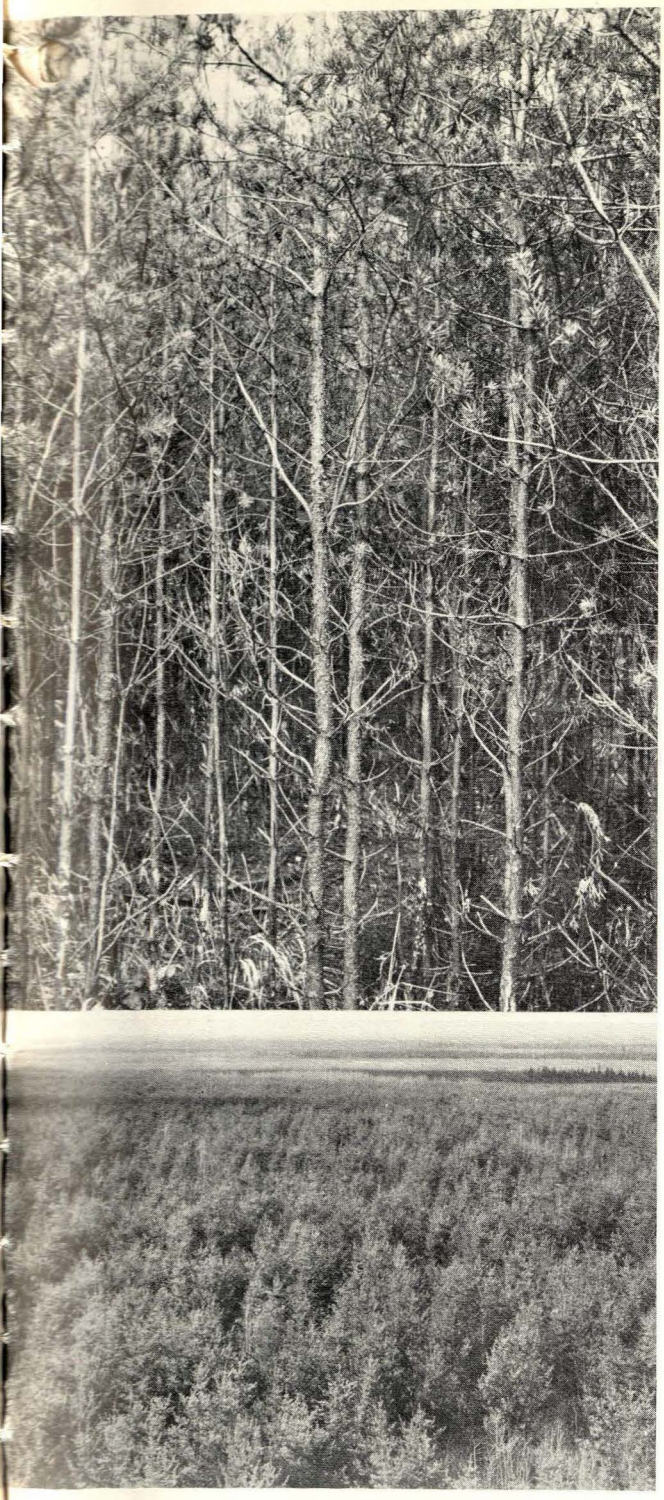

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FIGURE 1. — Two views of the Aurora jack pine direct seeding. In 1936 the area was burned over by a wildfire, destroying the layer of heavy duff as well as the rodent population. A broadcast seeding was made in spring 1937. Ten years later the area seeded on bare ground averaged 10,600 seedlings per acre.

SUBSEQUENT SEEDING TRIALS

The success of the seeding at Aurora did not arouse much general interest, probably because it was given little publicity. It likely was responsible, however, for at least some of the seeding trials put in by various members of the staff of the Lake States Forest Experiment Station in the late 30's. These and subsequent tests in the 40's and 50's were mostly with jack pine, but a few trials were also made with red pine, white pine, white spruce, black spruce, and balsam fir. Some were made in Minnesota on the Chippewa and Superior National Forests, and some in Wisconsin and Michigan.

Canadian foresters have also been interested in seeding, in fact, even longer than we in the Lake States. Their early studies, however, were reported only recently and are included here (Cayford, 1959; Haig, 1959).

The general details of these various trials are given by seeding methods under species. Others may have been installed, but they have not been reported in the common channels used for forestry publications.

The results of the seedings have been rated as to success in three groups, good, fair, and poor-to-failure, on the basis of the criteria shown in table 1. The standards set up are somewhat lower for spruces and balsam fir than for pines. This is because the spruces and balsam fir can stand more suppression and also tend to fill in by means of early self-seeding.

Jack Pine

The many trials of direct seeding with jack pine in the Lake States and adjacent Canada include almost all of the possible combinations of seeding methods and site preparation. They cover sites from eastern Ontario to western Manitoba. For convenience, they are grouped by the following seeding methods: (1) cone scattering, (2) broadcast seeding, (3) seed spotting, (4) seeding with hand tools, and (5) drill seeding.

Cone Scattering

Cone scattering or its variant, the scattering of cone-bearing slash, is being used successfully on disked or rock-raked ground to restock cutover jack pine lands on the Superior National Forest and elsewhere. Several pilot-scale applications are

TABLE 1. — *Criteria used to determine success in Lake States direct seeding trials*[1]

Results	Age of seeding	Jack, red, and white pine		Spruces and balsam fir	
		Stocking	Seedlings per acre	Stocking	Seedlings per acre
	Years	*Percent*	*Number*	*Percent*	*Number*
Good	2-3	60+	1800+	60+	1500+
	4-6	50+	1000+	50+	750+
	7-10	50+	700+	40+	500+
Fair	2-3	30-60	800-1800	30-60	500-1500
	4-6	30-50	500-1000	30-50	400-750
	7-10	30-50	400-700	30-40	300-500
Poor to failure	2-3	30—	800—	30—	500—
	4-6	30—	500—	30—	400—
	7-10	30—	400—	30—	300—

[1] *Adjustment in rating was occasionally made for trials with appreciably higher stands of seedlings but lower stocking than the values shown and vice versa.*

underway on the Tomahawk Sale. Since the cones open at different times, depending on their distance from the ground, the amount of shade, and other elements affecting their temperature, cone scattering has the advantage of making the seed available for regeneration for a much longer period — 2 to 3 years or more — than when seed alone is used.

This treatment on a disked area on the Kawishiwi Experimental Forest in northeastern Minnesota produced a stand of 4,300 jack pine seedlings per acre with 61 percent stocking at the end of the second growing season.[4] Cone scattering has shown fair results in Manitoba (Cayford, 1959).

Broadcast Seeding

Scattering the seed broadcast has been used more extensively with jack pine than has any other seeding method. Tests have been made on fresh burns and on sites prepared by mchanical means, using seed broadcast both in late winter on snow and during the growing season.

On burns. — Seeding on top of snow in late winter at Aurora, as already pointed out, was a failure (Roe, 1951). Seeding on bare ground, on the other hand, has generally turned out much better. On the Chequamegon National Forest in Wisconsin, seeding on a fresh burn proved successful (Stoeckeler and Limstrom, 1950); and another one on the Chippewa National Forest, using only ¼ pound of seed per acre a few days after a fire in late April 1949, gave good results. On the credit side, also, are the broadcast seeding at Aurora (Roe, 1951) and one that Shirley (1937) considered a failure, likely because he did not have full information on it. The latter, a 1.5-acre tract on the Kawishiwi Experimental Forest in northeastern Minnesota, was clearcut and burned in early July 1935. Strips seeded to jack pine in mid-May 1936 at 2 pounds per acre were then gone over lightly with a Rich fire tool. These showed 4,900 seedlings per acre and 83 percent stocking that fall after going through the 1936 drought. It is still a fully stocked stand.

Only partly successful, however, was the 122-acre seeding in June 1948, following a severe fire on the Tofte District of the Superior National Forest (fig. 2). The first block was sown to about 3 pounds of seed per acre; subsequent blocks averaged 1 pound. Duff consumption had been quite complete. A good rain had fallen at the completion of the job, but little occurred during the next 3 or 4 weeks. The results at the end of the second year follow (unpublished data):

Site:	*Area (acres)*	*Stocking (percent)*	*Seedlings per acre (number)*	*Sowing rate (pounds/acre)*
Upland	10	64	1,750	3.1
Semi-swamp	1	80	3,700	1.0
Upland	111	26	505	1.0

Even poorer were two other trials made on the Superior, one sown with a small amount of seed right after burning in spring 1942, the other with ⅜ to ½ pound of seed per acre in late May 1945 after a burn the preceding November. Both failed,

[4] *Much of the material given in this report is based on unpublished data in the files of the Lake States Forest Experiment Station. In the remainder of the report the reader may assume that test results not referenced to a specific literature citation are gleaned from unpublished Station data.*

likely because of poor destruction of the heavy duff and insufficient seed.

On mechanically prepared sites. — On most of the areas broadcast-seeded after mechanical treatment of the site, the ground was prepared with light farm disks in the earlier years and with the heavier Athens disks in later years (fig. 3). The first known trial of mechanical site preparation was made on the Duck Mountain Forest Reserve in western Manitoba in 1920 but was not reported until recently (Haig, 1959). Like most of the many subsequent trials, this involved seeding on bare ground and consisted of three ¼-acre plots broadcast-sown in May with 2, 3, and 4 pounds of jack pine seed per acre. Early results were excellent, but hare nipping in 1924 and again in the early 30's eventually wiped out the seedlings.

Canadian foresters have done considerable additional work of this type on the Sandilands Forest Reserve not far north of the Minnesota border. These seedings, totaling about 400 acres and put in during the periods 1925-28, 1943-45, and 1950-55, were described recently by Cayford (1959). Seed was broadcast from early April to mid-July and also in October at rates varying from 0.2 to 2.0 pounds per acre. Generally, the results were good. Ratings made 3 to 13 years after seeding showed that 19 of the 30 trials were well stocked — some were greatly overstocked as at Aurora (Roe, 1951) — 2 had fair stocking, and 9 were poor-to-failure.

On the Chippewa National Forest, broadcasting 1 pound of jack pine seed in late April 1940 on an area disked the preceding fall showed fair stocking the first year but poor results 3 years later.

A few trials of broadcast-seeding jack pine on disked sites have also been put in on snow in late winter. One such seeding with 0.8 to 1.6 pounds of seed per acre made in southeastern Manitoba in early April 1953 gave a well-stocked stand of seedlings (Cayford, 1959). But on the Chippewa, such seeding at 1 pound per acre both in mid-winter and in late winter (early to mid-April) 1940 showed poor results.

Seed Spotting

Seed spotting has been tested on prescribed burns, on disked or furrowed areas, and on unprepared sites. One test was begun in May 1942 on the Superior National Forest on a small area that had been burned the preceding fall. Seed was sown both with and without soil covering. Uncovered seed for some reason gave better results, showing 2,600 seedlings per acre and 70 percent

(F-450656)

FIGURE 2. — Fresh burns, such as that shown at Plouff Creek, Superior National Forest, often have ideal seedbed conditions and no rodent problem. But unless subsequent moisture conditions are favorable, broadcast seedings on such sites will give only fair to poor results.

stocking at the end of the third year compared to 1,550 seedlings and 50 percent respectively for covered seed.

Another test made in Ontario showed good stocking (77 percent) at the end of 4 years from both fall- and spring-sown jack pine which had been seeded on screened spots in a burn. Unscreened spots, on the other hand, were failures (Leslie, 1953).

Several attempts have been made to seed-spot jack pine on land that had been previously disked or furrowed. One test on an area of disked soil on the Chippewa National Forest failed the second year, likely because of the re-invasion of grass. Also a failure were trials in Manitoba of seed spotted in the bottom of furrows in June and November 1952 (Cayford, 1959). On the other hand, seed spotting after disking in jack pine clearcuttings showed much better results. Of four trials, one turned out poorly, but the other three showed 900 to 1,600 trees per acre with 45 to 60 percent stocking 7 to 9 years after seeding (Cayford, 1959).

Seed spotting on unprepared sites has generally been ineffective. Two tests made on the Superior in a jack pine clearcutting showed only a poor stocking at the end of 3 years, but a test in similarly cut jack pine in eastern Ontario had excellent results (Logan, 1951b). Trials made on both open sand plains and under adjacent poor-site aspen, also in eastern Ontario, failed (Horton and McCormack, 1961), as did six of eight ¼-acre plots so seeded on open jack pine land in Manitoba in the late 20's. Of the remaining two plots, one plot 3 to 6 years after seeding had a fair stand while the other was well stocked (Cayford, 1959).

Seeding With Handtools

At Aurora, a 1-acre tract burned in the fire of 1936, was seeded in 1937 with an Efco rake. This tool, resembling a potato hook, has a hollow handle containing the seed. After a spot is prepared with the rake, a few seeds are released and worked into the soil.

Germination was good and survival high, the plot showing 2,200 seedlings per acre at the end

(F-471816)

FIGURE 3. — Disked areas are also excellent seedbeds when moisture conditions are adequate, but they must be protected from rodents.

of 4 years. Many spots, however, had two to nine seedlings. Since most of these were still alive at 10 years, thinning was needed (Roe, 1949a). To be satisfactory, a tool should be designed to deliver fewer seeds per spot.

In 1953, the Station made a rather thorough trial of the Baker seeding tool. This was tested with jack pine and red pine seeds at six different locations on the Tomahawk Sale on the Superior National Forest. Seed was sown in May, June, July, September, and October on duff and on scalped spots with and without screening against rodents. Although the results were generally poor, some differences were evident; these were (Strothmann and Conover, 1960):

1. Spring and summer seedings of jack pine were better than fall seeding.
2. Scalped spots showed no consistent advantage over unscalped spots.
3. Screening was definitely beneficial.
4. Best results were obtained from the May and June seedings on an area that had been logged one year previously.

Drill Seeding

Drill seeding in furrows, using such machines as the Planet Jr. garden seeder, has been tested on both large and small tracts on the Nicolet National Forest in Wisconsin and the Chippewa in Minnesota (fig. 4). A large seeding on the Nicolet in the spring 1937 failed mostly because of drought, but heavy losses were also caused by smothering of the seedlings by leaf litter during the following winter (Stoeckeler and Limstrom, 1942). A detailed examination the second year showed a striking relation between stocking and depth to the water table. Areas where this was at 2 to 3 feet in midsummer had 4,000 to 6,000 seedlings per acre compared to 1,200 or fewer where the water table dropped below 4 feet. Subsequent trials on a small-plot scale showed fair and poor stocking at the end of the second season for fall and spring seedings, respectively. Losses were due mostly to lack of protection against rodents (Stoeckeler and Limstrom, 1942).

Large-scale drill seedings on the Chippewa showed variable results. One seeding put in in the spring of 1938 proved overstocked, but a repeat that fall failed as did one in the spring of 1939 and much of an even larger seeding made in the spring of 1942. Moisture conditions had been generally favorable; the failures were due mostly to washing and covering of the seedlings or to closing over of the furrows by side vegetation.

Special Seedbed Studies

In addition to trials of the various seeding methods, most of which were empirical, two seedbed studies deserving mention have been conducted.

The first of these, made by LeBarron (1944) in northeastern Minnesota, tested the germination and early development of jack pine and black spruce seeds and seedlings over a 2-year period. The trials included different types of seedbeds under different degrees of tree and low cover,

(F-273313)
FIGURE 4. — In one of the early seeding trials, grooves made with a wheel in the bottom of shallow furrows were seeded by hand.

both with and without protection against rodents and birds. Both species germinated best on bare mineral soil; results were less satisfactory on burned duff and scarified shaded surfaces and poor on undisturbed duff. Growth of the seedlings, however, was poorer on the bare soil than on the other three surfaces. In years with normal summer rainfall, growth was favored by the absence of both tree and low cover. The chief cause of mortality to seedlings was insects, mostly through defoliation. Damping-off fungi ranked second; heat, third; and drought, fourth. The importance of birds and rodents as seed-destroyers proved much smaller than expected.

In the second study, Beaufait (1960), working with jack pine in Lower Michigan, tested the effect of time of sowing on three different seedbeds under three light levels. He found that sowing early (late May) gave no advantage to the germinating seedlings over later sowing (mid- and late June). Although germination was best under one-third normal light, the seedlings showed poorer survival here than under either two-thirds light or full light. Of the different soil treatments, results on scarified soil were much superior in germination and survival than on burned and untreated soil.

Red Pine

Relatively little has been done in the Lake States with direct seeding of red pine. Most of the work consists of a few trials of seed spots on the Superior National Forest. Spots of five seeds each, covered with soil, were put in in the spring of 1944 on a disking that had settled over winter. These showed 65 percent stocking and 1,710 seedlings per acre the first year. By the ninth year, however, the stand was reduced to 24 percent stocking and 610 per acre, a fairly satisfactory stand.

Seed sown and covered in May 1947 on another settled disking, however, showed poorer results. Some had been water soaked, some stratified, and the rest not pretreated. Although the stratified seed germinated earlier, results of all treatments at the end of the first year were similar — 650 to 820 seedlings per acre and 30 percent stocking. At the end of the sixth year, stocking averaged only 19 percent and seedlings 425 per acre.

A third series of spots put in in May 1945 with covered and uncovered seed on an area burned for the purpose the preceding fall was a failure from the start. This was also true of another plot in the same burn on which 3 ounces of seed were broadcast per acre. Likewise, a 220-acre broadcast seeding (4 to 8 ounces) in a fresh burn on the Chippewa National Forest in May 1949 failed. In none of these trials was the seed protected against rodents.

In Wisconsin, Stoeckeler and Limstrom (1942 and 1950) compared fall versus spring seeding of red pine drilled in furrows. Results despite rodent losses the first year were fairly good; but subsequent losses, mostly from smothering of the seedlings by hardwood leaves, were heavy. At the end of the second year, stocking was only fair, and the seedings eventually failed.

A few seed-spot trials have also been reported from Canada, mostly from the Petawawa Forest Experiment Station. The earliest on record dates back to 1922 when covered red pine seed was sown on spots prepared in a 50-year-old aspen-birch stand that had been thinned to different intensities. Although survival 10 years later was fair, the seeding eventually failed because of the heavy competition from aspen suckers and hardwood sprouts (Fraser, 1952).

Later at Petawawa, a similar test was made in a jack pine clear cutting. This showed an excellent initial catch, but stocking dropped to 41 percent in 4 years and to less than 20 percent in 11 years. The losses were apparently due to the exposed open site (Logan, 1951b).

Poor results were also obtained from a test of covered and uncovered seed, sown with and without red lead treatment, on an open jack pine site and under an adjacent stand of light aspen. Only the seed sown under aspen and covered with ½ inch of soil showed fair stocking (40 percent) 5 to 6 years later; however, the seedlings had made but little growth. Seed protection was of some benefit (Horton and McCormack, 1961).

On the other hand, a test of seed spotting in the Port Arthur area was successful. Leslie (1953) cites excellent stocking at the end of 4 years from seed sown in a burn under screens, both in fall and spring; unprotected spots were a failure.

A test was also made with the Baker tool on the Superior on scalped and unscalped spots, with and without screening against rodents, in May, June, July, September, and October 1953. The results, generally poor, were best on scalped spots

that had been seeded in May or June and protected against rodents (Strothmann and Conover, 1960).

White Pine

Although white pine has a large seed and would thus seem to be an easier species to establish by direct seeding, little work has been reported on it. Most of this is from Petawawa where it was tested with the other native pines.

Seed spotted under an aspen-birch thinning there in 1922 showed fair to good survival 10 years later, but the seedlings were eventually choked out by aspen suckers and brush (Fraser, 1952). Fair early results were obtained from seed spots in a jack pine clear cutting in 1939, but the seedlings quickly failed and were a complete loss 7 years later, apparently because of the open site (Logan, 1951b). Seed sown in the 50's, both covered and uncovered, on an open jack pine site and under adjacent aspen of light stocking showed generally poor results except for the sowings under the aspen with a light cover of soil. These had about 45 percent stocking after 5 to 6 years, but the seedlings were so small that the job could hardly be considered fair (Horton and McCormack, 1961).

Another test at Petawawa involved seeding under 55-year-old white pine on small plots given the following surface treatments: exposed mineral soil, light burning, severe burning, and undisturbed duff. Since the seed was sown at the rate of one-half pound per milacre, the stand-per-acre figures have little meaning. When the test was closed at the end of 11 years, the best treatment was the severe burn. Exposed mineral soil was a close second, the light burn a poor third, and undisturbed duff poorest (Logan, 1951a). A test of white pine seed-spotting in a burn near Port Arthur was also successful where the spots were screened; stocking 4 years later was excellent for fall sowing and good for spring sowing. That on unscreened spots was poor for fall sowing and fair for spring sowing (Leslie, 1953).

In the Lake States only one test of white pine has been reported in recent years. This was a small trial of acid-treated seed made in Wisconsin. It showed high stocking on both screened and unscreened spots at the end of the first season but apparently failed later on (Stoeckeler and Limstrom, 1942, 1950).

White Spruce

The earliest direct seeding test known of white spruce was begun in Manitoba in May 1920. Seed was broadcast at 1, 2, and 3 pounds per acre on well-disked soil and then harrowed. The job was so successful that the ¼-acre plots still showed 3,400 to 5,000 seedlings per acre 27 years later and were in need of heavy thinning (Haig, 1959).

Similar seedings attempted in the Lake States have not turned out so well. One on the Chippewa National Forest, using 2 pounds of seed broadcast in November 1951 on snow on an area disked the previous summer, showed about 500 seedlings per acre with 30 percent stocking after the seventh year. Initial germination had been poor, probably because much of the seed eventually lodged on top of the litter from the hardwood overstory (70 square feet of basal area). There had also been heavy competition from herbs.

On the Superior National Forest, spotting the seed on a fresh disking in October 1945 showed fair to good results at the end of the first season where the seed had been covered with soil — 40 percent stocking and 1,500 seedlings per acre. But by the end of the sixth season, results were very poor, most of the loss having occurred during the first winter. On the other hand, seed spotting in May 1945 on an area burned the preceding fall gave results somewhat similar to those of the snow seeding on the Chippewa. At the end of the third season, stocking here averaged 30 percent and seedlings 625 per acre; results with uncovered seed were slightly superior to those with covered seed.

In the fall of 1938 white spruce was drill seeded in furrows in Wisconsin; this was a failure (Stoeckeler and Limstrom, 1942). Seed-spotting tests in Canada have also shown discouraging results. Leslie (1953) reports only fair results after four seasons from fall-sown, screen-protected seed, poor results for similar seed sown in spring, and a complete loss for unscreened seed; this trial was made in a burn. And seed sown in 1922 on prepared spots in a thinned aspen-birch stand showed poor survival (20 percent) 10 years later. Most of the loss was due to competition from aspen suckers and brush. The ability of this species to hang on under adverse conditions is brought out by the fact that, with no release, 11 percent of the spots still had 1 or more seedlings 26 years later, and these ranged up to 8 feet in height (Fraser, 1952).

Considerable light has been thrown on the seedbed requirements of white spruce by a study in northeastern Minnesota. Seed sown on three different types of seedbed in a clear cutting and under a medium overstory showed much the best germination and establishment on bare mineral soil. Results on duff were about the same as those on duff shaded by light slash. Survival at the end of 5 years was much superior under medium cover to that in the open (LeBarron, 1945).

Black Spruce

A few seeding tests of black spruce have been made both on upland and lowland. A replicated trial in Newfoundland in the spring of 1950 on a July 1949 burn showed trees averaging 1 foot in height at the end of 4 years, and the following stocking:

Broadcast seeded on snow, late April — 66 percent

Broadcast seeded on bare ground, mid-May — 29 percent

Seed pressed into bare mineral soil, mid-May — 54 percent

The good results are in large part due to the great amount of seed used — 11 pounds per acre. Germination, however, was only 40 percent (Dickson, 1956).

On the Superior National Forest, a broadcast seeding of 1 pound per acre in the spring of 1945 on a burn of the previous fall showed poor results the first year and had failed by the third season. However, seed spots put in at the same time gave much better results, particularly where the seed was covered with soil; these had 45 percent stocking and 700 seedlings per acre at the end of the third season. Another seed spotting on a fresh disking in the fall of 1945 got off to a much poorer start and had failed by the third year.

Seedbed studies made with this species in the forties show that on upland sites black spruce germinates best on bare mineral soil; burned duff and shaded scarified duff are less effective, and slash-shaded and undisturbed duff, poor. Survival and growth are better in the open than under partial tree cover or under low vegetation. Rodents were not important as a destructive agent; the chief causes of seedling mortality were various needle-eating insects, damping-off fungi, and heat (LeBarron, 1944, 1945).

Most of the lowland seeding trials of black spruce have been made on the Kawishiwi Experimental Forest. One in July 1947, consisting of pressing the seed with the foot into hummocks of live sphagnum moss in an open swamp, showed initial stocking of 96 percent. However, the fast-growing moss outgrew many of the seedlings during the first autumn, causing stocking to fall to 50 percent (Roe, 1949b). Little subsequent loss occurred; 5 years later stocking was 48 percent with the trees averaging 15 inches in height.

Further tests of this method, made in 1949 in the same swamp but earlier in the season and with smaller amounts of seed, had very poor results; the loss was due to moss smothering and to high water levels.

Subsequent trials were aimed at controlling the sphagnum competition with 2,4-D. These proved that the moss had to be sprayed well before seeding as the seedlings were injured by the herbicide. And if seeding was delayed too long, the moss would become re-established.

Since different sphagnum species seem to show differences in growth rate and other qualities affecting their value as seedbeds, this opens up an entire new field for study. Although the success ratio of lowland spruce seedings is low, the one good job suggests that seeding could well be a practical way of restocking swamps with black spruce (fig. 5).

Balsam Fir

Several trials with balsam fir have been put in on upland sites in northern Wisconsin and one or two in northern Minnesota. Most were seed-spotted either on disked land in furrows, in small openings in a hardwood stand, or under sprayed brush. On two areas, the seed was broadcast after disking. Two tests were also made of seed spotting on lowland.

Disked areas in poorly stocked aspen, in cut-over jack pine, and in heavy sod were spring-sown with stratified seed. In the first two conditions, some spots were covered with soil, others left uncovered; in the heavy sod, some spots were screened against rodents. The first-year results were fairly good under light aspen cover but poor elsewhere. The latter areas eventually failed, but the one under light aspen still showed 750 trees per acre and 30 percent stocking after 11 years. The trees had made little height growth, however (Stoeckeler and Skilling, 1959).

(F-452494)

FIGURE 5. — The possibilities of seeding black spruce in swamps need thorough study. These 2-year-old seedlings have outgrown the competing sphagnum moss and are well established.

In Wisconsin, spotting stratified seed in furrows proved a failure because of the eventual suppression of the seedlings by sod in the furrow bottoms (Stoeckeler and Skilling, 1959). This factor was also most important in a similar seeding on the Kawishiwi Experimental Forest. Stocking here, 69 percent at the end of the second year, was only 26 percent 5 years later.

Seed spots made in a hardwood opening (spring and fall seeding, both screened and unscreened) and under sprayed brush (fall seeding, screened and unscreened) had fair initial stocking but eventually failed, the former after 11 years, the latter after 4 years (Stoeckeler and Skilling, 1959).

Of two broadcast seedings, one was spring-sown with less than ½ pound of seed per acre on disked sod in a very light hardwood stand on the Nicolet National Forest; the other was snow-seeded in November with 2 pounds per acre on a disking under poor-quality hardwoods (70 square feet of basal area) on the Chippewa National Forest. The spring sowing had a fair initial stand (1,130 seedlings per acre) but was down to only 50 per acre by the second fall (Stoeckeler and Skilling, 1959). Results of the snow seeding were considerably better, 1,760 seedlings at the end of the first season and 875 seedlings with 40 percent stocking at the end of the seventh year. And on small plots here where the ground cover had been sprayed, the stand after 7 years averaged 1,750 seedlings per acre with a stocking of 55 percent.

The best results of all the balsam fir seeding trials known were obtained on screened spots that had been fall-sown on a swamp margin site — 90 percent stocking and a tree percent of 11 after 10 years. High early stocking also occurred in another seeding on sphagnum moss in a swamp, but after the fourth year all the trees died from moss smothering or from drowning (Stoeckeler and Skilling, 1959).

In a special seedbed study, LeBarron (1945) found mineral soil much superior to duff and to slash-covered duff as a seedbed for balsam fir. Survival 5 years later, however, was much better under a medium cover of trees than in the open.

AERIAL SEEDING

As far as is known, only one direct seeding of conifers has been attempted from the air in the Lake States and adjoining Canada. This was made with pelleted seed by the Ontario Department of Lands and Forests and was a failure (Rudolf, 1949). In eastern Canada, Thomson (1949) reports a 3,000-acre aerial job in New Brunswick in the winter of 1947-48. Part was on an area burned in 1947, the rest on one burned in 1944. About 3,400 pounds of seed were used, including red pine, white pine, balsam fir, white spruce, red spruce, Norway spruce, and northern white-cedar. At the end of the first year, the 1947 burn showed 50 percent stocking and up to 13,000 seedlings per acre; the older burn was much poorer. Apparently no later results have been published.

In southeastern Maine, a 320-acre portion of a fall 1947 burn was also seeded from the air in

early March 1948 just prior to a snowstorm. White pine was used at the rate of 5,000 seeds per acre. Counts made 4 years later showed that the seeding had been unsuccessful, possibly because of the severe drought during the first year (Hart, 1954). About 1,900 acres of other burns in New England were also seeded to white pine from the air during February and March of the same year, using 4,000 to 56,000 seeds per acre. Counts the first fall showed up to 2,475 seedlings per acre, but subsequent results do not seem to be available (Westveld, 1949).

While results of aerial seeding have not shown much promise in the Northeast and in eastern Canada, outstanding success with this technique is being obtained in the South. It has been used there on a large scale for the past 6 or 7 years (Derr and Mann, 1959; Mann and Derr, 1961). It need hardly be stressed, however, that seed sown from the air is subject to all of the factors causing loss as seed broadcast from the ground. Successful ground-seeding techniques must, therefore, be worked out before the operation can be taken to the air. This, of course, was the approach used in the South and is the only sound way to attack the problem.

SEED REPELLENT TREATMENTS

A few years ago much interest was aroused by the possibilities of sowing coniferous and other seeds embedded in pellets composed of various more or less inert materials that would disintegrate under favorable moisture conditions. The objectives were to provide (1) better control of seed distribution, and (2) favorable conditions for germination through the incorporation of rodenticides, insecticides, and fungicides in the material used to make up the pellet (Rudolf, 1949).

Trials have been made with pelleted seeds of Lake States conifers by various agencies including Michigan State University, Consolidated Water Power and Paper Company of Wisconsin, Ontario Department of Lands and Forests, the U.S. Fish and Wildlife Service, and the Lake States Station. The pellets have been hand-sown both in the field and in the nursery, and they have also been broadcast from aircraft. Tested were the three native pines, the two spruces, and balsam fir (Rudolf, 1949, 1950). In only one case, a test of black spruce in the field, did the pelleted seed show better results than bare seed. In one other trial, jack pine seed embedded in one type of pellet gave about as good germination as unpelleted seed when sown in the nursery at ¼-inch depth. On the other hand, seed in another type of pellet gave poorer results.

Because of these poor results and the considerable additional weight involved,[5] pelleting of conifer or other seeds has never been used to any extent for direct seeding, at least in the Lake States. Instead, interest in repellents for rodent control has shifted to the use of the light coatings of rodent-toxic and bird-repelling materials which have been so practicable and effective in direct seeding of conifers in the South. Such coatings are cheap, relatively simple to apply, and add only 25 to 35 percent to the weight of the seed. It, therefore, seems doubtful that seed pelleting will ever have much application under Lake States conditions. However, if materials are developed that appear to have merit for this purpose, the method should receive additional study.

GENERAL CONCLUSIONS

Everything considered, the various trials made since 1937 make direct seeding appear somewhat more promising than it did in Shirley's report (1937). Excluding the work of Beaufait (1960) and LeBarron (1944, 1945), 126 trials and tests of direct seeding have been made or reported on upland sites in the Lake States and adjacent Canada since 1936. In addition, six tests were made on lowland soils. Of the 132 tests, about 40 percent have turned out well, 12 percent fair, and the remainder have been poor or failures.

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[5] *Pelleted jack pine seed has been found to be 9 to 25 times heavier than bare seed (Rudolf, 1950).*

On four-fifths of the good jobs, jack pine was used. Success was also obtained in three trials each of white spruce, black spruce, and balsam fir and one each of red pine and white pine.

Of the 38 jack pine trials with good results, 26 were put in disked areas by broadcast seeding or seed spotting and 7 more by one or the other of these types of seeding on burns. Several of the broadcast seedings have produced overdense stands because of the use of too much seed; the cost was likely much in excess of that of planting.

Broadcast sowing of large amounts of seed on a disking also resulted in the three successful white spruce seedings and, on an upland burn, in two good black spruce seedings. And a disked seedbed was largely responsible for two balsam fir seedings with good results.

The remaining successful jobs were seeded with the following species and methods:

Jack pine — two spot seedings on otherwise unprepared sites, 1 drill seeding in furrows, 1 with cone scattering on disked ground, and seeded on a burn with the Efco rake.

Red pine — 1 seed spotting in a fresh burn.

White pine — 1 seed spotting in a fresh burn.

Black spruce — 1 seed spotting on sphagnum moss.

Balsam fir — 1 seed spotting on mineral soil on a swamp margin.

All told, 86 percent of all successful seedings were either broadcast- or spot-seeded on disked areas or on fresh burns; whereas only 66 percent of the trials were of these types. The great importance of some kind of site preparation is also emphasized by the fact that 46 and 49 percent respectively of the seedings on burns and on disked areas were successful compared to only 13 percent of those on unprepared ground.

There were naturally failures even where the site was well prepared for seeding. Seeding on the snow in late winter showed up poorly except for one area with jack pine and one trial in black spruce where 11 pounds of seed were used per acre. The reason for the usual failure of late snow seeding is not known, but it may be due to the freezing at night of seed which has absorbed considerable moisture from the wet surface of the snow during the often warm days.

The one job with the Baker Tool, a comprehensive test of jack pine and red pine, also turned out poorly. For unknown reasons initial germination was poor.

Most of the drill seeding in furrows also failed. Seedings by this method, which Shirley (1937) considered the most dependable of those he appraised, usually showed a good initial catch. But the seedlings were either buried by washing in heavy rains or smothered over winter by leaf litter drifting into the furrows. And the surviving seedlings often became overtopped by vegetation growing on the sides of the furrows.

Competition also was the main source of seedling loss in seeding trials on disked sod and was apparently of great importance in reducing stocking on many others, especially those rated fair or poor in stocking. Seedlings from seedings are even more vulnerable to competition than planted trees. This fact apparently was overlooked, and release operations were invariably neglected (fig. 6).

Probably the most important reason for poor initial stocking of seedlings was the loss of seed to rodents and perhaps birds. On few areas was any attempt made to protect the seed. Where screened and unscreened seedings were used in parallel, the difference in favor of screening was typically large. Coating the seed with red lead also gave some rodent and bird protection.

Unfavorable weather conditions, so far as is known, were responsible for poor results on only two of the seedings made or reported since 1937. Heavy losses were caused by drought in a furrow seeding in Wisconsin in 1937, and in a broadcast seeding in the Plouff Creek burn in 1948. Elsewhere, such losses seem to have been negligible.

Where comparisons were made of spring versus fall seeding, spring usually gave better results for nondormant seed such as jack pine and red pine. Fall seeding, on the other hand, was better for the dormant seeds, white pine and white spruce.

Pretreatment such as stratification or water soaking appeared to cause somewhat earlier germination of nondormant seeds such as red pine, but the advantage soon disappeared. Perhaps in a season with critical moisture conditions in midsummer, the earlier germination would have been of benefit.

Covering the seeds with soil gave erratic results, sometimes favorable, other times unfavorable.

Summing up, the various trials of direct seeding made in the Lake States and adjacent Canada during the past 40 years have two major indications. First, direct seeding, although uneconomic in several trials, has had better results than is commonly believed. Second, most of this past work has been so haphazard, of such poor design, and so poorly carried through that direct seeding cannot be put into practice with any assurance that the good results sometimes obtained can be duplicated. Greatly needed, therefore, are well-planned comprehensive seeding studies that will evaluate all of the important factors leading to success or failure. Not until such studies are made will it be known when, where, and how direct seeding can be used reliably as a substitute for forest planting in the Lake States.

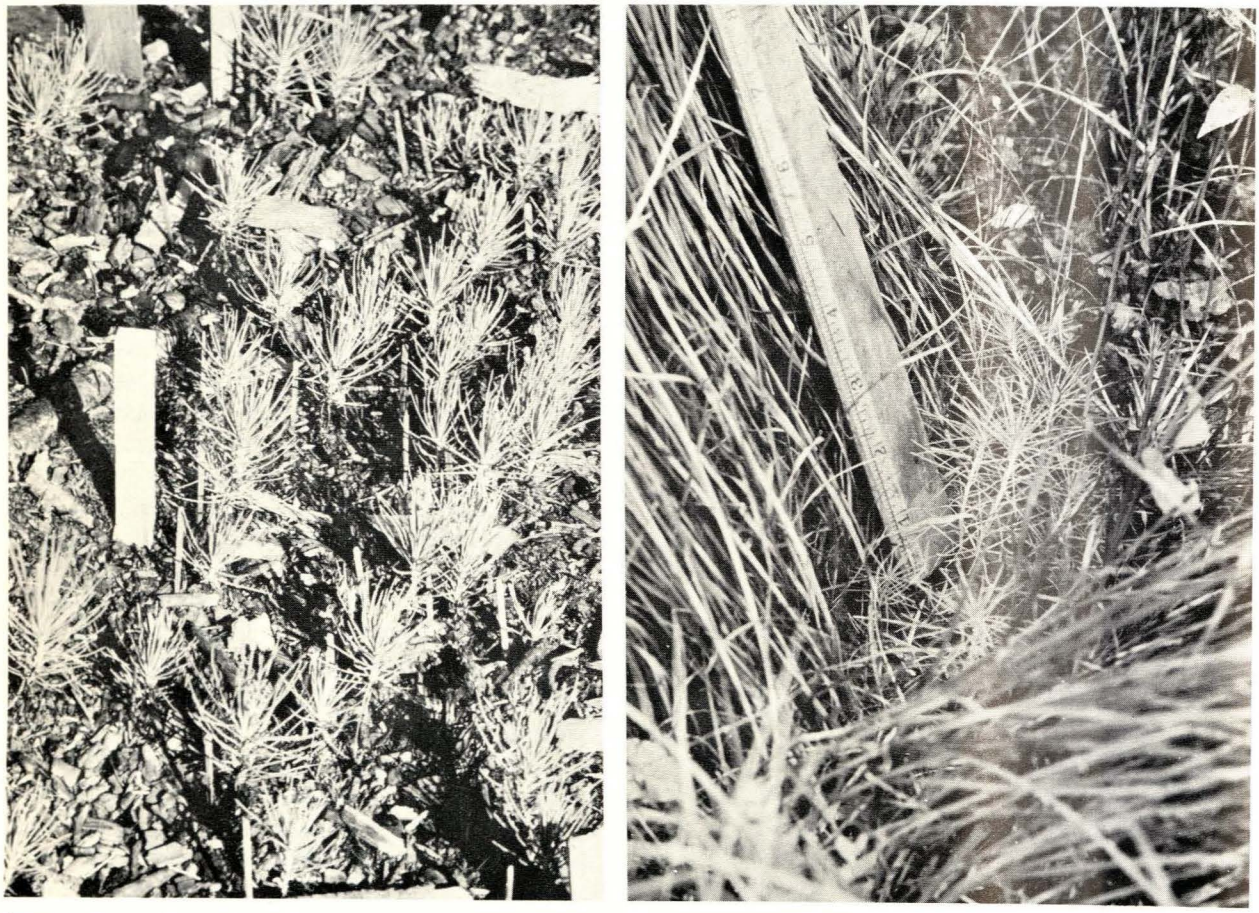

FIGURE 6. — Competing vegetation was the most serous cause of mortality in the seedings. Compare the thrifty vigorous 1-year-old jack pine seedlings on the weed-free area at the left with the spindly ones growing under grass on the right. (F-354515, 354519)

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